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STUDENT OUTLINE

FUNDAMENTALS OF ELECTRICAL SYSTEM COMPONENT REPAIR

LEARNING OBJECTIVES: There are no learning objectives or tests for this lesson. However, you will be using the material covered here throughout the electrical portion of this course.

OUTLINE

1. REVIEW OF THE BASIC PRINCIPLES OF ELECTRICITY

a. Remember high school science? Matter is everything that has mass or occupies space. To help understand electricity, we should know that everything is made up of billions of atoms. Atoms can be broken down into protons, neutrons, and electrons.

b. Atoms

(1) An atom is constructed somewhat like the solar system, where the sun is the center or core and the planets revolve in orbits around the sun.

(2) The protons and neutrons will concentrate in the center and the electrons will be distributed in rings varying distances from the center. Electrons on the inner rings are called bound electrons and the electrons on the outer ring are called free electrons. We'll talk more about this in a little while.

(3) A proton is said to have a (+) positive charge of electricity and an electron is said to have a (-) negative charge of electricity. A neutron has no electrical charge or is neutral.

(4) The proton and the electron are attracted to each other (opposites attract). The centrifugal force of the electron spinning around the proton holds them apart. The attraction and the centrifugal force balance each other out and this holds the electron in its ring.

(5) If the attraction between the proton and electron is broken or is not strong enough to hold the electron in its path, the electron will get away. Like a ball tied to a string spinning around in the air, the string is the attractive force and the centrifugal force holds the ball out, but if the string is cut, the ball flies away.

c. Electricity is the flow of electrons from atom to atom in a conductor. What causes the electrons to flow? If an outside force acts on an atom, it will cause the electron to break free and go to the next atom and so on. Here is how it works.

(1) Let's take a copper wire and place a negative charge at one end and a positive charge at the other end.

(2) Before we go on, let me say there are two electrical theories: the "old" conventional theory and the electron theory.

(a) The conventional theory says that electrons flow from positive to negative. This is what most people have heard and believe.

(b) The electron theory says that electrons flow from negative to positive. This is now thought to be the correct theory and the one that we will talk about.

(3) Now back to our wire. The positive charge at the end of the wire is stronger than the positive charge of the single atom. The free electron of the atom will be attracted to the stronger positive charge, causing it to break free and leave the atom.

(4) This leaves the atom short one electron, so that atom now has a strong positive charge and will attract an electron from the next atom and so on. This will continue as long as the positive and negative charges are maintained at the end of the wire.

d. Any material that allows electrons to flow through it is an electrical conductor. If an element has less than four electrons on the outer ring, it is considered to be a good conductor. Gold, silver, copper, and aluminum are good conductors. Gold and silver are the best, but because of cost, they are impractical for common usage. Aluminum has a higher resistance than copper, so copper is mainly used.

e. Any material that blocks electron flow is an electrical insulator. If an element has more than four electrons on the outer ring, it is considered to be an insulator. Common insulating substances in automotive applications are rubber, plastic, bakelite, varnish, fiberboard, and ceramic glass.

f. If an element has four electrons in the outer ring, it is a semiconductor. These are the elements used in a diode. Diodes, sometimes referred to as rectifiers or rectifying diodes, will be covered later in the lesson.

g. Earlier I said electricity is the flow of electrons. The flow of electrons is called current. It is measured with an ammeter connected in series with the circuit and the units of measurement are called amperes, or amps.

h. Electrons are caused to flow by a difference in electron balance. In a circuit, electrons will flow from an area where they are concentrated to an area where they are lacking. This difference is called potential difference, electrical pressure, electromotive force, or more commonly, voltage. The higher the voltage or difference, the greater the current flow. Voltage is measured with a voltmeter connected parallel to the circuit and the units of measurement are called volts. We will talk later about types of circuits.

i. Voltage causes electrons to flow but there is a resistance to flow.

(1) Even a good conductor has resistance. This resistance is caused by the energy needed to break the electron free from the atom. It takes more voltage to overcome this resistance. Resistance is measured in ohms with an ohmmeter

(2) The resistance of a conductor changes with its length, diameter, composition and temperature.

(a) A long wire has more resistance than a short wire of the same diameter and material.

(b) A steel wire has more resistance than a copper wire.

(c) A small diameter wire has more resistance than a larger wire.

(d) Resistance in metal increases with an increase in temperature and resistance in nonmetal decreases with an increase in temperature (glass is a good insulator at room temperature but poor when heated to red hot.)

j. A very basic circuit consists of a power source, a unit to be operated, and a wire connecting the two together. If the unit to be operated is to be controlled, a switch will be included in the circuit.

k. The body and frame in a vehicle are usually made of steel. This is used to eliminate one of the wires from all of the circuits. By attaching one of the battery terminals to the frame, any electrical component can be wired by hooking up one side to the battery and the other to the frame. This is called grounding. The frame will complete the circuit back to the battery.

l. A series circuit consists of two or more electrical components that are connected end-to-end so that any current flow depends on a complete path through all of the components. Any break in the circuit kills the entire circuit. Two 12 volt batteries connected in series will produce 24 volts but the amperage will remain the same.

m. A parallel circuit is two or more components connected on separate branches of the circuit. If one component fails, it will not affect the other components. Two 12 volt batteries connected in parallel will only produce 12 volts but the amperage will double.

n. A series-parallel circuit is a combination of both circuits. If we take four 12 volt batteries and connect two each together in series, then connect the two sets in parallel, we can double the voltage and amperage.

2. BASIC PRINCIPLE OF MAGNETISM AND ELECTROMAGNETIC INDUCTION

a. Because of your previous training in this subject, I'm just going to give you some established rules of magnets and magnetism.

(1) A magnet has a north and south pole.

(2) There are magnetic lines of force that flow around the magnet from the north pole into the south pole.

(3) The magnetic lines of force taken together are referred to as the magnetic field of the magnet.

(4) The stronger the magnet, the more lines of force.

(5) The lines of force never cross each other.

(6) The lines of force act like rubber bands and try to shorten to a minimum length.

(7) The lines of force repel each other along their entire length and try to push each other apart.

(8) The rubber band characteristic opposes the push apart characteristic.

(9) As we stated earlier, opposite poles attract and like poles repel each other. These rules apply to both permanent magnets and electromagnets.

b. If current flows through a wire, it will produce a magnetic field around the wire. The stronger the current, the stronger the field.

(1) If the wire is turned into a loop, the lines of force will follow the turn in the wire.

(2) If two turns are made in an insulated wire, the lines will join together and circle both loops as if they were just one loop. However, the field is twice as strong with the same amount of current flow.

(3) Many loops in a wire formed into a coil will greatly increase the strength of the magnetic field. Because the fields of each loop will all join together, this coil is an electromagnet. If we change the direction of current flow through the coil, polarity will also change.

(4) The only insulation for magnetic lines of force is an air gap. The stronger the magnet, the more air the lines can pass through. Soft iron is a good conductor of magnetic lines of force. It is 2500 times more permeable

than air. If we wrap the coil around a soft iron core, the lines of force can pass through the soft iron instead of air and this will strengthen the electromagnet even more.

(5) We can change the strength of the electromagnet by changing the number of loops of wire or by changing the amount of current flowing through the coil.

c. Once a soft iron core has been magnetized and the magnetizing force has been removed, the soft iron will retain a small amount of magnetism. This is called residual magnetism.

d. Three things are required to produce electromagnetic induction:

(1) A magnetic field.

(2) A closed conductor, because we need a complete circuit.

(3) Relative motion between the field and the conductor.

e. Current can be induced or caused to flow in a conductor if it is moved through a magnetic field.

(1) As the wire or conductor is moved through the field between two magnetic poles, it cuts the lines of force.

(2) Current will be induced into it because the lines resist being cut and will tend to wrap around the wire. This produces a magnetic whirl around the wire which pushes the electrons through the wire.

(3) The current will change directions or alternate as we move the wire up and down through the field.

f. We can change the amount of current induced by changing the strength of the magnetic field, the amount of conductor, or the speed that the conductor cuts the lines of force.

g. Electromagnetic induction can be accomplished using three methods:

(1) by causing the conductor to spin within the field, as in a generator,

(2) by causing the field to spin within the conductor, as in an alternator, and

(3) by causing the field to build and collapse, as in an ignition coil.

3. CONSTRUCTION AND OPERATION OF COMPONENTS

a. Generator

(1) The field windings with pole shoes are nothing more than an electromagnet. They are made of many coils of fine wire wrapped around the pole shoes, which are constructed of soft iron. They produce the magnetic field that the conductor cuts.

(2) The armature is the conductor. The armature core is made of laminated iron. It is wound with coils of copper wire and mounted on a shaft with a commutator on one end. There is one set of commutator segments for each coil in the armature.

(3) As the armature spins in the generator, it will cut the weak magnetic field produced by the residual magnetism in the pole shoes. This will induce a small voltage in the armature. That small voltage is routed back to the field windings and will increase the magnetic field, causing a larger voltage to be induced into the armature. When the voltage is sufficient to charge the battery, the cut out relay of the regulator will close and send the voltage to the battery. The voltage regulator will also control the output of the generator through the field circuit.

b. Alternator

(1) The field in an alternator is the rotor. The rotor is constructed with two pole pieces that have fingerlike projections on them. They sandwich the field windings on the shaft. One pole piece will be north and the other will be the south pole of the magnetic field. Each end of the field winding will be connected to a slip ring that the brushes will ride on.

(2) The conductor in an alternator is the stator. There are two types of stators; the delta wound and the wye wound stator. The stator is normally designed with three separate windings so that it produces three separate alternating currents. This is known as three-phase output.

(a) In the wye type stator, each phase is wound around a laminated, soft iron core. All three phases will come together at one end. The other end will go back to the battery, via the circuitry.

(b) In the delta type stator, all three phases are wound around a soft iron core, just as in the wye type. However, phase one will end where phase two begins, phase two will end where phase three begins, and phase three will end where phase one begins. It's sort of a series type set up. Each output lead will have two wires coming to it. A double wound delta will have four wires at each output lead and twice as many windings.

(3) In the film we just watched, we saw that the current was alternating back and forth in the armature of the generator but the switching action between the brushes and commutator caused the generator to put out direct current. An alternator uses diodes to do the same thing. A diode is a devise that will allow current to pass through it in only one direction. It can be thought of as a one way electrical check valve. There are positive and negative diodes. A positive diode will allow positive current to flow through it and stop negative current, while a negative diode will allow negative current to flow through it and stop positive current.

(4) Some alternators have a component called a diode trio. It is three positive diodes that take current straight from the stator to the rotor to increase the strength of the field, much like some generators do. In some alternators, there will not be a diode trio but current will flow from the positive diode back to the rotor to do the same thing.

(5) Advantages and disadvantages

(a) Advantages

1 It is smaller and lighter than a generator with the same output.

2 It will produce current at a much wider speed range.

3 The brushes are required to carry only enough current to produce the field and they last longer since they ride on smooth slip rings.

(b) Disadvantages

1 Alternating current produced by an alternator must be rectified to direct current with diodes which are usually pretty durable but can be destroyed by reverse polarity and excessive heat.

2 An alternator does not retain residual magnetism; therefore, you can't push a vehicle "to start it" if it has a dead battery. However, this is not a real problem to military vehicles now since most of them are diesel.

(6) The rotor is energized by the battery through the regulator. As the rotor spins within the stator, current is induced into the stator and goes to the diodes. There are six diodes, three negative and three positive diodes, one each per phase. The diodes sort out the current and send it back to the battery. The output of the alternator is controlled by the regulator. The regulator senses the requirement placed on the electrical system and will cause the alternator to put out more or less to meet that requirement by controlling the current going to the rotor.

(7) Inductor type brushless alternator

(a) The rotor has two laminated pieces mounted on a core shaft. It has no windings on it. The field windings are mounted in the center of the housing and surround the center of the shaft. When the winding is excited, the rotor becomes magnetized.

(b) This alternator has two wye type stators, one on either side of the field windings.

(c) This alternator works like any other alternator except it doesn't have brushes since the fields don't rotate. It's sort of a combination of a generator and alternator.

(d) The generator like field windings are energized by the battery which will magnetize the rotor spinning in the center. The magnetic field of the rotor will cut the windings of the stators and induce voltage into them. The current is then sent back to the battery through the diodes. The diodes in this alternator do the same job as in other alternators but there are more of them.

d. A starter is constructed basically like a generator except the windings in the fields and armature are much heavier to handle the amperage they will be subjected to.

(1) In the starter, rather than taking current from the armature, current is sent to it and also to the fields. This magnetizes the armature and the fields. Remember, like poles repel and opposites attract. In the starter, when the north pole of the armature lines up with the north pole of the fields, they will repel each other, causing the armature to spin. Then, just at the precise moment that the south pole of the armature lines up with the north pole of the fields, the switching action between the brushes and the commutator will reverse the direction of current flow in the armature. This will reverse the polarity of the armature and once again, the like poles will repel each other. This will continue as long as current is supplied to the starter.

(2) In the film, the operator manually engaged the starter drive and closed the switch to send current to the starter motor. We have a magnetic switch called a solenoid to do that for us. A solenoid has a wire coil in it with a moveable plunger in the middle. The plunger is held off-center by a spring. Once the coil is energized, it creates a magnetic field. It will pull the plunger back and center the mass of the plunger in the magnetic field. The plunger is connected to a shift lever on one end and has a copper disc on the other. When the solenoid is energized, the plunger will engage the starter drive gear with the engine flywheel. At the same time, the disc will make contact with the starter terminals and send current to the motor to crank the engine. When the solenoid is de-energized, the spring will disengage the starter drive and open the switch to stop the starter motor.

4. <u>BENCH TEST PROCEDURES</u>

a. Parts of a Delco alternator will not fit in a Leece-Neville alternator but they contain basically the same components. If you can test one, you can test the others and only occasionally do you run into an oddball that uses different procedures. This also applies to starters and generators.

b. The multimeter is our most used piece of test equipment, so first I'll explain how we are going to use it and what we are checking for.

(1) There are four basic conditions that we test for during troubleshooting and testing electrical systems, circuits, or components. These conditions are: continuity, an open circuit (referred to as an open), a short circuit (called a short), and a grounded circuit (most often called a ground). All of these conditions are often wrongfully called a short. During testing, we are checking for these conditions or the lack of these conditions, depending on the situation.

(2) Circuits

(a) Continuity is a complete circuit.

(b) An open is a break or interruption in the circuit, such as a broken wire or a connection that has come loose.

(c) A short occurs when one wire in the circuit touches another wire in the circuit and part of the circuit is by-passed or shorted. An example of this is when wiring insulation between two wires fails and the wiring makes contact.

(d) A ground occurs whenever any part of the wiring circuit is toughing the vehicle frame. A ground involves accidental or intentional contact between the circuit and the frame.

(3) When we check for continuity, we will use the lowest scale of the ohmmeter. Our reading is how much resistance is in the circuit. If there is no reading (infinity), an open is indicated. Too low of a reading would indicate a short and too high of a reading would indicate excessive resistance, possibly corrosion.

(4) When we check for a ground, we will use the highest scale of the ohmmeter. If we get a reading, the component is grounded.

(5) When we check a diode, we will use the diode scale or X1000 scale.

c. On all components, you start with a good general visual inspection. Look for anything unusual, such as cracks, breaks, chips, scraped insulation, burnt or broken windings, and so on. On an armature, you also have to inspect the commutator. Make sure the segments aren't touching each other and nothing is between the segments except the insulation. If you find any of this, you must clean it out. Make any measurements called for. If it passes the visual inspection, we can bench test it.

(1) Check the commutator segments for continuity, using either the ohmmeter or the test leads of the growler. All of the segments should have continuity with each other.

(2) Check the armature for a ground. With the ohmmeter, check from any commutator segment to the shaft. The ohmmeter reading should be infinity.

(3) Check for internal shorts with the growler. Place the armature on the growler, turn it on, and with a thin strip of metal, go around the armature. If the metal strip vibrates, the armature is shorted. The exception to this is the armature for the 40 amp generator; it should cause the metal strip to vibrate.

(4) If the armature fails any of these tests, it must be replaced.

d. The next component to test is the field windings. Once again, perform a visual inspection first, then check the field windings for continuity and for a ground. There are many variations of fields, so a general statement on how to check them wouldn't be in order. We will demonstrate that during the classes on individual components.

e. All rotors are pretty much the same. After you visually inspect the rotor, check for continuity between the slip rings and for a ground between one slip ring and the shaft. There should be continuity between the slip rings but no ground between the slip rings and shaft. Replace the rotor if either test fails.

f. On the stator, we check for continuity between the leads 1 to 2, 1 to 3, and 2 to 3. We should have continuity. On a delta wound stator, this test is inconclusive because a phase could be open and we would still get a reading. Check for a ground between a stator lead and the iron core. There should not be a ground.

g. There are many variations of diodes but they all test the same. The only way to determine if you have a positive or negative diode is to test it with an ohmmeter or test light. To start with, put the ohmmeter on the scale with the diode symbol or the X1000 scale. Touch one lead to one side of the diode and the other lead to the other side, then reverse the leads. You should have a reading one way and not the other. If you don't get a reading either way or if you get a reading both ways, replace the diode.

h. We don't have the equipment to properly check a capacitor or filter but we can check to see if it is working at all. Put the ohmmeter on its highest scale. Put one lead on the capacitor lead and the other multimeter lead on the capacitor housing. The reading should climb, then come back down. If it doesn't, reverse the leads. This shows us that the capacitor is loading and unloading. If it does, we're going to call it good; if it does not, we will replace the capacitor.

i. The last component we are going to talk about is the regulator. Most equipment today has a solid state regulator on it. The only thing we can do to it is visually inspect it and do a performance check. A way to do this is to put the regulator on a known good alternator and see if it works. If it does, it's good; if it doesn't, it's bad.

<u>REFERENCES</u>:

Delco Remy, Fundamentals of Electricity and Magnetism
TM 9-8000